AN ESTIMATE OF THE SIZE AND STRUCTURE OF THE KAMINURIAK CARIBOU HERD IN 1977

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AN ESTIMATE OF THE SIZE AND STRUCTURE OF THE KAMINURIAK CARIBOU HERD IN 1977

DOUG HEARD

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ABSTRACT

The size of the calving ground segment of the Kaminuriak caribou herd was estimated at about 27,000 animals in June 1968. Most surveys since 1968 have not produced an accurate population estimate; however, subsequent surveys that were accurate indicated that the herd has declined since 1968. I conducted a survey of the calving ground between 2 and 12 June 1977. The sample units in the survey were line transects. The calving ground was divided into three strata within which sampling effort varied according to density. Post-calving groups were segregated by observers on the ground between 15 and 17 June. In September, caribou were segregated from the air in 1976 and 1977 and from the ground in 1977. The calving ground population was estimated at 16,503 $\pm$ 1,936 (S.E.) caribou over 1 year of age. The total population was estimated at 44,095 caribou, excluding calves. Ninety percent of the non-calf animals on the calving ground were breeding females. The peak of calving was 7 June in the north half of the calving ground, and 14 June in the south half. Fall segregations indicated that calves (3 month old caribou) made up 23% of the total population in September 1976, and at least 20% in September 1977. Most of the problems affecting previous surveys were avoided in this study. The 1977 population estimate is the most precise obtained to date. This estimate supports the hypothesis that the Kaminuriak caribou herd has declined since 1968.

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1. INTRODUCTION

The Kaminuriak caribou herd has been studied more intensively than any other herd of barren-ground caribou in Canada. Detailed work on the population dynamics of this herd began in 1968 with the first estimate of the number of animals found on the calving ground. In June, Parker (1972) estimated about 27,000 animals over 1 year of age on the calving ground.

Surveys carried out between 1971 and 1973 (Land and Bowden 1971, Bowden and Timmerman 1972, Land and Hawkins, 1973) were beset by serious procedural difficulties. As a result, none of these surveys produced a reliable estimate of the calving ground population (Cook and Jacobson 1976). In 1976, the calving ground population was estimated at about 19,000 animals (Hawkins and Calef 1980), a substantial decrease from 1968 although the change was not significant ($p > 0.1$). The main objective of my research was to obtain an estimate of the size of the calving ground population in 1977 that was sufficiently precise to confirm or refute the evidence that the size of the Kaminuriak herd is diminishing.

In order to obtain a reliable population estimate, it was necessary to avoid as many of the difficulties that plagued previous censuses. Cook and Jacobson (1976) discussed six serious drawbacks of the 1971 to 1974 surveys:

(1) The sampling error, inherent in a quadrat sampling design, was very high.

(2) The high percentage of animals in groups too large to count probably introduced sustantial bias into the population estimate.

(3) The data were not analyzed statistically, therefore are almost useless because the reader has no idea of their reliability (precision).

(4) Adjustment had to be made for the blind spot under the airplane.

(5) The three herd composition parameters required to produce a total population estimate were not collected during the same year as the census.

(6) The number of unobserved animals within the census zone (the observer visibility bias) was unknown.

In 1977 I attempted to solve most of these problems.

2. METHODS

2.1 Calving Ground

2.1.1 Sample Design

The problems of previous surveys were avoided in this survey in the following ways:

(1) I hoped to reduce sampling error by using transects rather than quadrats as my sample unit and by dividing the calving ground into strata of similar density.

(2) To reduce the proportion of animals in groups too large to count accurately, I conducted the census at the peak of calving when the animals were likely to be most evenly distributed across the census zone.

(3) The data were analyzed statistically.

(4) The transect strip was set up such that the blind spot under the plane was eliminated from the sample unit.

(5) I attempted to collect data on 2 of the 3 parameters necessary to estimate the total population.

(6) No attempt was made to determine the visibility bias of the observers. The results of an experiment by Fischer and Duncan (1976) indicated that 19.2% of the caribou on transect are overlooked. Further testing of visibility bias was beyond the scope of this research. The results of Fischer and Duncan's experiment were surprisingly close to the widely used but subjective estimate of 20% (Thomas 1969, Parker 1972); therefore, I assumed that observer bias was 20% in this survey also.

I decided that stratified random sampling, where the sampling units were line transects, was the best design for a survey of caribou on a calving ground. Sample error results when animals are clumped together instead of uniformly dispersed. By stratifying the calving ground into density regions, and using line transects instead of quadrats the effect of clumping is reduced (Norton-Griffiths 1975).

Proper stratification also increases the precision of the population estimate because the variation in the distribution of animals within each stratum is less than the variation in the distribution of animals across the whole census zone (Siniff and Skogg 1964).

The distribution and density of animals was determined prior to the survey by flying evenly spaced transects over the area

traditionally used for calving by the Kaminuriak herd (Fig. 1). The "reconnaissance" flights were spaced at 19.3 km intervals and provided the data necessary to delimit the census zone (the calving ground), to divide the area into strata of similar density, and to allocate the optimum sampling effort to each stratum. Reconnaissance was carried out on 2 - 5 June, 1977, about 1 week prior to the peak of calving (10-15 June, Parker 1972). The boundaries of the calving area were established where caribou density became low, or where most of the animals observed were yearlings or bulls. The calving ground could not be delimited by the presence of calves because few had been born.

I distinguished three strata (Fig. 1) based on the reconnaissance data. In Stratum I and II, I selected transects with a probability proportional to their length with the restriction that the mimimum separation between neighbouring transect line centres be 1.6 km in Stratum I, and 1.2 km in Stratum II. I incorporated these restrictions into my sample design to reduce the effect of caribou moving between adjacent transects. Stratum I was surveyed on 7 June, and stratum II on 12 June, 1977. The survey of stratum III on 14 June, was abandoned because the distribution of caribou was noticeably different from that observed on the reconnaissance flights. It was therefore necessary to use the data obtained from the systematic reconnaissance flights to estimate the number of caribou within Stratum III. Population estimates and variance can be reliably calculated from data obtained from a systematic sampling design, although the estimate of variance may be slightly over-estimated (Heard et al. 1980, Pennycuick et al. 1977).

2.1.2 Flight Details

All transects were flown at an altitude of 122 m and an airspeed of 160 to 177 km/hr in a Cessna 337 with two observers in the back seats. Total flying time for reconnaissance and census flights was 30 hours. Each observer counted all caribou on one side of the aircraft within a strip 0.8 km wide on reconnaissance flights or 0.4 km wide on survey flights. Strips widths were calculated by flying over appropriately spaced markers on the ground, and marking both the window and the wing strut so that both the inner and outer boundaries of the strip could be seen. Thus the blind spot beneath the plane was not included as part of the area surveyed. I sat in the front seat and plotted the location of each sighting on a 1:250,000 scale topographical map, while the observers recorded the number and classification of all caribou on tape, thus never having to look away from the transect strip. Observers classified caribou as calves, bulls or "others". Calves were easily distinguishable by their small size, and bulls were distinguishable by the presence of antlers in velvet. No other age or sex of caribou could be reliably distinguished.

2.1.3. Methods of Analysis

I calculated the population estimates of caribou within Stratum I and II as follows (Jolly 1969, Method 3):

$$\hat{Y}_i = Z_i \bar{d}_i$$

where

$\hat{Y}_i$ = the population estimate in the ith stratum.

Z_i = the total area of the ith stratum; and

$\bar{d}_i$ = the unweighted mean density of caribou in the ith stratum.

The variance of the population estimate within each stratum is:

$$\text{Var}(\hat{Y}) = \frac{(Z)\ (Z - \sum z_i)\ \left[\sum d_i^2 - (\sum d_i)^2 / n\right]}{(n)\ (n-1)}$$

where:

Var $(\hat{Y})$ = the variance of the population estimate,

Z = the total area of the stratum,

z_i = the area of the ith transect,

n = the number of transects surveyed, and

d_i = the density of caribou in the ith transect.

The equation for the calculation of the variance of $\hat{Y}$ incorporates the finite population correction term $(Z - \sum z_i)/Z$ into Jolly's Method 3 equations. This was necessary because I drew samples without replacement. Thus, if the area sampled ($\sum z_i$) was increased, the finite population correction term would decrease and the variance of Y would decrease.

I treated the data from Stratum III as if they were from a random sample of transects. The analysis followed Jolly's (1969) Method 2 and Heard et al. (1980):

$$\hat{Y} = Z\bar{d}$$

where:

$\hat{Y}$ = the population estimate;

Z = the total area of the stratum, and

$\bar{d}$ = the weighted mean density of caribou.

The variance of the population is:

$$\text{Var}(\hat{Y}) = \frac{(N)(N-n)}{n}\left[S_y^2 - (2S_{zy})(\bar{d}) + (\bar{d})^2 (S_z^2)\right]$$

where:

N = the maximum number of transects that could be surveyed,

n = the number of transects surveyed,

S_y^2 = the variance between animals counted in all the units.

$$= \frac{1}{n-1}\left[\Sigma y^2 - (\Sigma y)^2/_n\right]$$

S_z^2 = the variance between the area of all the sample units.

$$= \frac{1}{n-1}\left[\Sigma z^2 - (\Sigma z)^2/_n\right], \text{ and}$$

S_{zy} = the covariance between the animals counted and the area of each unit;

$$= \frac{1}{n-1}\left[\Sigma (z)(y) - (\Sigma z)(\Sigma y)/_n\right]$$

2.2 Calving Ground Segregations

On 15, 16, and 17 June 1977, I flew in a helicopter to four areas of the calving ground where there were high densities of caribou. We approached on foot to within 200 m of the caribou and observed them through a 20x spotting scope. Caribou were classified as: bulls, cows with or without an udder, cows with or without a calf, adults of unknown sex, yearling males, yearling females, yearlings of unknown sex, male calves, female calves, or calves of unknown sex (Bergerud 1964, 1971). We classified as many caribou as possible, but were careful to avoid counting an individual

more than once. Very little effort was spent attempting to determine the sex of calves.

2.3 Fall Segregation

Aerial segregations were carried out from a Cessna 185 on 11 and 12 September 1976 by the author and G. Calef, and between 14 and 20 September 1977 by the author and J. Donaldson. In 1977, ground segregations were also done on 14, 18, and 20 September. Aerial segregation flights concentrated on areas of high caribou densities, but also included other areas so that the distribution of caribou could be determined, thus the results would be more representative of the total caribou population than would the ground counts. In 1976, aerial segregations were flown only north of 63°30' N but in 1977 flights were more extensive, extending as far south as 61°31' N.

Ground segregation locations were selected where there were large numbers of caribou near a lake suitable for landing. As in the spring, only bulls and calves are distinguishable from the air, but mature bulls, 2 or 3 year old bulls, calves, adult cows, and male and female yearlings could be distinguished during fall ground segregations.

3. RESULTS

3.1 Calving Ground Census

3.1.1 Defining the Calving Ground and Delimiting Strata

Caribou density declined rapidly north of reconnaissance transect 1 and south of number 10 (Fig. 1). These transects were at the limits of the traditional calving ground (Parker 1972). Incidental observations also indicated that caribou density was extremely low beyond these limits. The eastern and western boundaries of the calving ground were established at the last caribou sightings on the end of each transect. The average distance flown beyond the extreme sightings was 16.2 + 4.5 km (n = 20, Fig. 1). The calving ground covered 18,488 km^2 and lay between 62°10' N and 63°54' N, and between 93°16' W and 97°15' W (Fig. 1).

The results of the reconnaissance survey indicated that in two areas of the calving ground, caribou density was much higher than the average. I designated these areas Stratum I and Stratum II (Fig. 2 and Table 1). Stratum III encompassed the remainder of the calving ground.

3.1.2 The Calving Ground Population Estimate

The estimate of the number of caribou 1 year of age and over on the entire calving ground was 16,503 ± 1,936 (Table 2). There were about the same number of caribou in each stratum, but the density among strata varied considerably (Table 2). There was no significant difference between the number of caribou over 1 year of age counted by each observer per transect [Wilcoxon (1945) matched pairs signed ranks test; n = 40, Z = 0.558, p = 0.58)]. The transect totals for each observer, each class of caribou, and each stratum, are presented in Appendix A.

3.1.3 Group Size and Dispersion

The average group size and the number of caribou estimated in groups too large to count accurately was highest in Stratum I and lowest in Stratum III. In Stratum I, there were 831 caribou over 1 year of age in 105 groups (range 1-63 caribou/group). Five other groups were too large to count accurately and the number of caribou in them could only be estimated. The number of caribou estimated in these five groups was 821 (range 112-300) or 48.9% of the total. The mean size of all 109 groups was 15.2 ± 3.6 (S.E.) caribou over 1 year of age. In Stratum II, only two groups of caribou were too large to count accurately. The estimated size of these two groups combined was 138 animals or 12.1% of

the total. The mean size of 137 groups was 3.9 ± 0.35 caribou (range 1-30). These groups were small enough to be counted accurately. Over the entire calving ground, the mean size of all groups was 7.5 caribou (3,325/443), and the number of caribou in groups too large to count accurately was 28.8% (951/3,325) of the total.

I considered each location point where I saw caribou to be equal to one linear mile of transect because this was as close together as the numbers could be written on the map. To test whether or not caribou were randomly distributed in Stratum III, I compared the distribution of caribou group sizes per location point to a Poisson Distribution. The very high X^2 value obtained indicated that the caribou were not randomly distributed, but were highly clumped ($X^2 = 415$, df = 4, $p < 0.001$). Since caribou were even more clumped in Strata I and II than in Stratum III, it is obvious that caribou were not randomly dispersed in these areas either.

3.2 Calving Ground Segregations

3.2.1 Group Composition

The results of the calving ground segregations are based on a classification of 632 caribou over 1 year of age (Table 3). Samples were taken from caribou in post-calving aggregations ranging in size from about 100 animals to well over 1,000. Breeding females (i.e. those with visible udders) comprised 89.6% of the caribou over 1 year of age on the calving ground (Table 3). The proportion of breeding females to total non-calf caribou on the calving ground, and the proportion of breeding females to total females was dependent on the location of the sample ($p < 0.005$ in both cases; Table 3).

This non-random distribution is difficult to explain but should be kept in mind when future calving ground segregations are done. For example, samples should be taken from as many different locations as possible to obtain representative segregation data.

3.2.2 Timing of Calving

By plotting the ratio of calves to total animals versus time, I hoped to estimate the date of peak calving. I determined the ratio of calves to total animals from all observations where complete calf counts were obtained, whether caribou were observed from the air, on or off transect, or from the ground. The data indicated that calving was not synchronous over the whole calving ground. North of 63° N (Fig. 1), the peak of calving was on 7 June, while south of 63° N, the calving peak was 1 week later (Fig. 3).

By 15-17 June, ground segregations on the calving ground, showed that only 93.8% of the cows with distended udders were still accompanied by a calf (Table 3). Cows with distended udders, but not accompanied by a calf, did not appear to be still pregnant. Such cows had probably calved earlier, on the average, than those cows still accompanied by a calf since few unaccompanied cows still had antlers (6.1% vs 16.6%, $G = 3.22$, $0.1 > p\ 0.05$, Table 4). Moreover, the proportion of unaccompanied cows was higher on the north part of the calving ground (6.8%), where the peak of calving was earlier than on the southern part (4.1%), ($G = 1.27$, $p < 0.01$).

3.3 Fall Segregations 1976 and 1977

Caribou tended to occur in groups of between 40 - 80 animals in the fall of 1976, and in groups of between 20 - 30 animals in the fall of 1977. Group composition in both years was extremely variable, with the proportion of bulls in groups of at least 10 animals varying from zero to 100%.

Calves represented 26% of the population segregated from the air in the fall of 1976 (Table 5). Mature bulls may have been under-represented in this sample. They comprised only 19% of the non-calf populations, whereas they usually represent about 30% of a caribou population (1977 data Table 5, Skoog 1968, Parker 1972). Aerial segregations in 1977 indicated that calves made up 20% of the total population and bulls made up 28% of the adults (Table 5).

Ground segregations indicated that mature bulls made up 37% of the adults (Table 6). Because the aerial segregations were based on a much larger sample and were obtained over a much wider area, they are more likely representative of herd composition. Thus mature bulls appear to have been over-represented in the ground segregation counts. Young bulls associated with mature bulls (unplublished field notes) and were presumably over-represented also.

I allowed for this sampling bias by making two adjustments. I assumed mature bulls made up only 28% of the population as indicated by the 1977 aerial segregation data. Animals designated as young bulls probably included all 2 year olds and about half of the 3 year olds. I assumed that both age classes made up 6% of the adults (Parker 1972). The resulting composition data are shown in Table 6. Yearling recruitment was about 10% and calves made up about 28% of the fall population if these assumptions are accurate. The sex ratio displayed in Table 6 was derived from the above assumptions, thus I have no reliable estimate of the sex ratio based on 1977 data.

The aerial segregations probably represent the best estimate of the proportion of calves (3 month old animals) in the population (20%, Table 5), but ground segregations results suggest that it may be higher (Table 6).

3.4 Estimate of Total Herd Size

To obtain an estimate of the number of caribou in the Kaminuriak herd, I used the following calculations:

1. The estimate of the number of caribou on the calving ground (Y: Table 2) was multiplied by the proportion of breeding females on the calving ground (Table 3) to obtain the number of breeding females in the total population.

2. The proportion of breeding females in the total population was then calculated by multiplying the proportion of all females in the population (Table 6) by the proportion of the total females that breed.

3. The total population estimate is then calculated by dividing the number of breeding females by the proportion of breeding females in the total population.

I did not attempt to determine the ratio of breeding to total females. To estimate this parameter, it is necessary to know: (a) the proportion of females in each age class; and, (b) the age-specific fecundity.

Estimates of age-specific pregnancy rates have been similiar among years and among herds (Table 7). Since pregnancy rates have always been observed to be high (about 90%) in females over 3 years of age, the effect of variation in the age structure on the reproductive rate was assumed to be negligible (Bergerud 1974, 1978). Parker (1972) estimated that the ratio of breeding females to total females was 0.694. I assumed that this value was representative of the herd in 1977 also.

The estimate of the number of caribou over 1 year of age in the Kaminuriak herd in June 1977 is therefore:

$$\frac{(16503)\ (0.896)}{(0.604)\ (0.694)} = 35{,}276$$

In order to make this estimate comparable to those of previous surveys (eg. Parker 1972), it must be increased by 25% - the traditional correction factor for animals overlooked during the census. The revised estimate is 44,095 (35,276 x 1.25).

Every parameter used in calculating the final population estimate has some error associated with its measurement. The precision of the total population estimate is dependent on the magnitude of these errors. Unfortunately, the precision of the total population estimate cannot be calculated exactly because there is no way to calculate a variance for the proportion of females in the total population (since I have adjusted my data), nor can I estimate how closely Parker's estimate of the proportion of females that breed, represents the Kaminuriak herd in 1977. I guessed at the combined error of these two parameters and calculated a variance for the total population estimate (Appendix B). The calculations indicated that there is a 95% chance that the size of the Kaminuriak herd is between 30,000 and 57,000 animals.

4. DISCUSSION

4.1 Sampling Methods

The 1977 calving ground census overcame most of difficulties encountered in previous censuses (Cook and Jacobson 1976). The division of the calving ground into strata reduced the variance considerably; the 95% confidence limits as a percent of the population estimate was much lower for the combined estimate than the average of the individual strata (23% vs 41% Table 2, see also Caughley 1977a, Heard et al. 1980).

Since caribou on the calving ground were aggregated, the use of transects probably produced a more precise population estimate than if the same amount of effort were used to sample quadrats (Norton-Griffiths 1975).

Relatively few caribou overall (29%) were in groups too large to accurately count. This represents some improvement over earlier surveys. In 1971, 89% of the total caribou were in groups too large to accurately count, and in 1974, 47% could not be accurately counted (Cook and Jacobson 1976). I do not know when surveys could be done to ensure more even dispersion of caribou. Since practice improves an observer's ability to estimate the size of large groups (Sinclair 1977), pre-census training in visual estimation is probably the best solution.

Most, but not all of the problems with previous surveys were overcome. Three herd composition parameters are required to extrapolate from the calving population size to an estimate of the total population. I made no attempt, however, to determine the proportion of females that breed. Fall ground counts were biased toward males. Results would have been more accurate if sufficient time and money were available to increase the sample size. The other problems with earlier surveys were easily avoided. I defined the transect strip boundaries so that it was not necessary to correct for the blind spot under the plane; I applied descriptive statistics to all data possible; and I collected sufficient data on the composition of the calving herd to estimate the proportion of parous cows on the calving grounds.

Randomly selected transect locations introduced unnecessary complications into the calving ground census. This is especially true when combined with the restrictions I imposed to avoid the problem of caribou moving between adjacent transects. A systematic selection of transects is much simplier. "So long as the sitting of systematic transects is not biased with respect to what lies on the ground (the actual distribution of animals), the axioms of the statistical model (of random sampling) are not grossly violated" (Caughley 1977a). Moreover, systematic sampling may provide a more precise population estimate than random

sampling (Caughley 1977a, Caughley 1977b, Cochrane 1977, Pennycuick et al. 1977, Heard et al. 1980).

4.2 The Calving Ground Census

The size of the calving ground, as I defined it, was much larger than in previous years (Table 8). However, 57% of the caribou were concentrated in only 15% of the area (Table 2). In other years, caribou were probably distributed so that there was a more abrupt change in density at the edge of the calving ground. Thus, previous investigators may not have had to include as much area of low caribou density to make sure they had censused the entire calving ground population.

As a result of our sampling methods, this census is the most precise done to date (Table 8). The accuracy of the population estimate cannot be measured, but there is no reason to believe it was different from other censuses (Parker 1972).

Parker (1972) estimated that the calving ground population in 1968 was about 27,000 (before he corrected for an observer bias of 20%). Thus, it appears that there was a substantial (39%) decline in the calving ground segment of the Kaminuriak caribou herd between 1968 and 1977. The 1977 estimate also reflects a decline from June 1976 when the calving ground population was estimated at 18,888 animals (Hawkins and Calef 1978). Thus, the 1977 calving ground population estimate suggests that the Kaminuriak herd has declined since 1968 and is still declining. (Figure 4, Table 8).

4.3 Herd Composition and the Calving Ground

The calving ground herd structure had been studied only once before. The major difference of herd structure between 1977 and 1968 (Parker 1972) was in the proportion of breeding females on the calving ground. Parker estimated that 80% of the adult animals on the calving ground were breeding females, whereas my figures indicated 89.6%. Parker equated breeding females with cows accompanied by calves on 15 and 26 June (Parker 1972). If a breeding female is defined as one with a distended udder (Bergerud 1964), my data indicated that by the same dates, 6.2% of breeding females were not accompanied by calves. In 1977, cows with calves made up 84.4% (498/590) of the total adult population on the calving ground. This proportion is not significantly different from Parker's estimate of 80% (523/654: $G = 2.05$, $p > 0.01$). However, the calculations of total herd size depends on the proportion of breeding females. Thus, Parker probably underestimated the calving ground population by about 6%.

4.4 Timing of Calving

The occurrence of two calving peaks suggests that there were two sub-populations of caribou on the calving ground in 1977. These sub-populations must also have mated at different times. This could be explained by the following assumptions:

1. These sub-populations were separated during the rut, and

2. The females of each rutting group remained together throughout the winter, or at least reunited prior to calving, and remained separate from the other group on the calving ground.

Evidence from other years supports each of these assumptions. Parker (1972) observed that in 1968 the peak of calving differed between the southern and northern part of the calving ground with the northern group calving 1 week before the southern group. Parker's observations from the winter of 1967-68 showed that the early calving cows had rutted and wintered on the tundra separately from the others. Some, or all of the Kaminuriak herd wintered on the tundra in 1975-76 (Fisher et al. 1977) and 1976/77 (D. Stewart pers. comm.). The results of radio tracking (Miller et al. 1975) and tag returns (Parker 1972) indicate that Kaminuriak caribou tend to remain with the same individuals throughout the year.

4.5 Early Calf Mortality

By 15-17 June, calving ground segregations showed that only 93.8% of the cows with distended udders were still accompanied by a calf (Table 3). Potential explanations are that the other cows were still pregnant, their calves had died, or because it was not unusual for a mother and calf to drift over 100 m apart in a large group, and the calf was simply overlooked. If the cows with distended udders that were not accompanied by a calf had not yet given birth, they should have appeared pregnant, but they did not. A higher proportion of unaccompanied cows relative to cows accompanied by calves should still have had hard antlers since antlers are usually retained until just after parturition (Kelsall 1968, Bergerud 1976). This was not the case. Only 6.1% of unaccompanied cows had either one or two antlers, while 16.7% of cows with calves still had at least one antler (Table 4). This indicates that unaccompanied cows may have calved earlier than those still with calves ($G = 3.22$, $0.1 > p > 0.05$). If unaccompanied cows did calve earlier, they would have had a higher probability of losing their calves by the time of this survey. This argument does not imply that there is any selective disadvantage associated with calving early, but it implies that the culmulative probability of calf death increases with age. Thus, the

calves of unaccompanied cows probably had died and this early mortality was about 6.2% of cows with distended udders (100 - 93.8).

The early calf mortality of 6.8% in the north half of the calving ground (15 and 17 June) was slightly higher than in the south half 4.1% ($G = 1.27$, $p < 0.1$). This result further supports the suggestion that caribou in the north half of the calving ground calve earlier than in the south half.

4.6 Fall Segregations

The estimate of recruitment in 1977 (9.9%) was similiar to Parker's estimates for 1967 (8.9%), 1968 (10.0%), and 1969 (11.4%, Parker 1972). The estimate obtained in this study of at least 20% calves in the herd in September is much higher than Parker's estimate of 15%. I cannot explain this difference.

The results of fall segregations were unreliable. The ground segregation counts were obviously biased, since sample size was small and bulls were under-represented in the sample. The final calculations had to be based on assumptions. Subsequent work on other herds has indicated that fall segregations are much more representative when carried out during the rut in mid-October (D. Heard, field notes). Unfortunately, freezing weather conditions at his time necessitate the use of helicopters which are often prohibitively expensive.

More accurate estimates of total population can be obtained only through refinement of the methods for collectiing herd structure data. Refining the methodology has proven successful in obtaining more accurate calving ground population estimates. There is certainly potential for a similiar improvement in collecting data on herd structure.

4.7 Total Herd Size

The calculation of a total population estimate is based on the calving ground estimate and the herd structure. Since the accuracy of the data on herd structure is unknown, only the calving ground population estimates should be used to determine the trend in the population size. However, for a more detailed analysis of the population dynamics of a caribou herd, it is necessary to use total population estimates because mortality estimates can only be applied to the population as a whole.

The 1977 estimate of the total herd size is the lowest ever obtained. The population was estimated at 63,000 in 1968, (Parker 1972), 49,000 in 1974 (Hawkins and Howard 1974) and

44,000 in 1976 (Hawkins and Calef 1980). Heard and Calef (1979) suggested that the Kaminuriak Herd has declined because the combined effects of hunting (>6%/yr.) and natural mortality, largely wolf predation (8.5%/yr.), have exceeded the average annual recruitment to this herd (10%/yr.).

Table 1. A comparison of the density of caribou per stratum between the reconnaissance and census surveys of the Kaminuriak herd in 1977.

Stratum	Caribou Density	
	Reconnaissance Caribou/km^2	Census Caribou/km^2
I	6.1	6.2
II	1.8	2.2
III	0.5	-

Table 2. Densities and population estimates of Kaminuriak caribou on the calving ground in 1977.

Stratum	Mean density caribou/km^2 d	Stratum area (km^2) Z	Population estimate $\hat{Y}$	Number of transects surveyed n	Number of transects possible N	Population variance Var ($\hat{Y}$)	95% confidence limits[3] of Y	C.L. % of $\hat{Y}$
I	6.2[1]	810	5,043	16	44	1,473,132	±2,586	±51.3
II	2.2[1]	1,917	4,312	15	58	526,150	±1,556	±36.1
III	0.5[2]	15,761	7,148	10	120	1,748,604	±2,991	±23.0
Overall	0.85[2]	18,488	16,503	41	222	3,747,886	±3,794	±23.0

[1] Weighted mean per transect.

[2] Weighted mean (total caribou/herd area).

[3] 95% confidence limits (C.L.) of $\hat{Y}$ = S.E. ($\hat{Y}$) x $t_{0.05}$

where: S.E. ($\hat{Y}$) = $\sqrt{\text{Var } (\hat{Y})}$

and $t_{0.05}$ is for n-1 degrees of freedom if $n < 30$

or $t_{0.05} = 1.96$ if $n > 30$ (Norton-Griffiths 1975)

Table 3. Reproductive status of Kaminuriak caribou on the calving ground in 1977.

Class	Total	Percent	S.E.[1]	Number or percent per area				
				15 June	16 June	17 June a.m.	17 June p.m.	G. Stat.[2]
Breeding females	566			260	121	150	35	
Barren females	35			6	16	10	3	
Yearlings	25			4	6	11	4	
Bulls and Adults of unknown sex	6			1	4	1	0	
Total	632			271	147	172	42	
Total females	601			266	137	160	38	
Breeding females/total	566/632	89.6	±3.81	95.9	82.2	87.2	83.3	24.5**
Barren females/total	35/632	5.5	—	2.2	10.9	5.8	7.1	—
Yearlings/total	25/632	4.0	—	1.5	4.1	6.4	9.5	—
Breeding females/total females	566/601	94.2	±2.39	97.7	88.3	93.8	92.1	15.0**
Barren females/total females	35/601	5.8	—	2.3	11.7	6.2	7.9	—
Females with calves/breeding females[3]	498/531	93.8	±3.77	90.0	95.9	98.7	—	—

1 After Snedecor and Cochrane (1967)

2 Test of independence among days (=areas)

3 This information not collected on 17 June p.m.

** $p < 0.01$

Table 4. Antler frequency of cow caribou on the Kaminuriak calving ground.

Udder	Calf	Numbers of hard antlers	Number of females	Percent of total
+	+	0	415	83.3
+	+	1	33	6.6
+	+	2	50	10.0
			---	----
			498	99.9
+	-	0	31	93.9
+	-	1	0	0.0
+	-	2	2	6.1
			---	----
			33	100.0
-	-	0	16	45.7
-	-	1	2	5.7
-	-	2 (in velvet)	17	48.6
			---	----
			35	100.0

+ present

- absent

Table 5. Number of caribou in each age and sex class as determined by aerial segregations in September 1976 and 1977.

Date	Mature bulls (% of adults)	Others (% of adults)	Total adult[1]	Calves (% of grand total)	Grand total
1976					
11 September	113	425	538	178	716
12 September	186	838	1,024	370	1,394
Total	299 (19.1)	1,263 (80.9)	1,562	548 (26.0)	2,110
Adjusted[2]	541 (30.0)	1,263 (70.0)	1,804	548 (23.3)	2,352
1977					
14 September	59	571	630	136	766
15 September	87	132	219	53	272
18 September	164	360	524	131	655
19 September	28	199	227	96	323
20 September	277	285	562	133	695
Total	615 (28.4)	1,547 (71.6)	2,162	549 (20.3)	2,711

1 Adults = 1 year and older

2 Bulls adjusted to be 30% of adults (see text for explanations).

Table 6. Number of caribou in each age and sex class as determine by ground segregations in September 1977.

Date	Bulls		Yearlings		Cows	Total adults	Calves (% of grand total)	Grand total
	mature	young	males	females				
14 Sept 1977	14	8	1	4	39	66	25	91
18 Sept 1977	25	19	3	1	6	54	6	60
20 Sept 1977	25	7	2	0	17	51	12	63
Total	64	34	11		62	171	43	214
Percent of Adults	37.4	19.9	6.4		36.3	100.0	20.1[1]	-
Adjusted Total[2]	31	7	11		62	111	43	154
Percent of Adults	27.9	6.3	9.9		55.9	100.0	27.9[2]	-

Total	Male	Female	
	44	67	111
Percent	39.6	60.4	100.0

1 Percent of Grand Total

2 See text for explanation

Table 7. Age specific pregnancy rates of caribou from different populations.

Age at conception (months)	Age at parturition (months)	Percent of age class giving birth Kaminuriak herd (Dauphine 1976) 1966	1967	1968	Alaska caribou (Skoog 1968)
3	12	0	0	0	0
15	24	0	6	0	13
27	36	41*	58*	46*	61
39 +	48 +	91*	92*	87*	89

* No significant differences among years.

Table 8. Summary of all Kaminuriak calving ground censuses.

Year	Population	Calving ground area Km^2	95% confidence intervals as percent of estimate	Source of Data
1968	27,178	6,066	33	Parker (1972)
1971	19,026[1]	4,784	178	Land and Bowden (1971)
1972	13,495[1]	5,021	71	Bowden and Timmerman (1972)
1973	9,914[1]	2,995	53	Land and Hawkins (1973)
1974	21,403	11,045	38	Hawkins and Howard (1974)
1976	18,888	9,763	29	Hawkins and Calef (1980)
Mean	18,317	6,622	67	
1977	16,503	18,488	23	This study

[1] Not acceptable as reliable estimates (Cook and Jacobson 1976, Heard and Calef 1979).

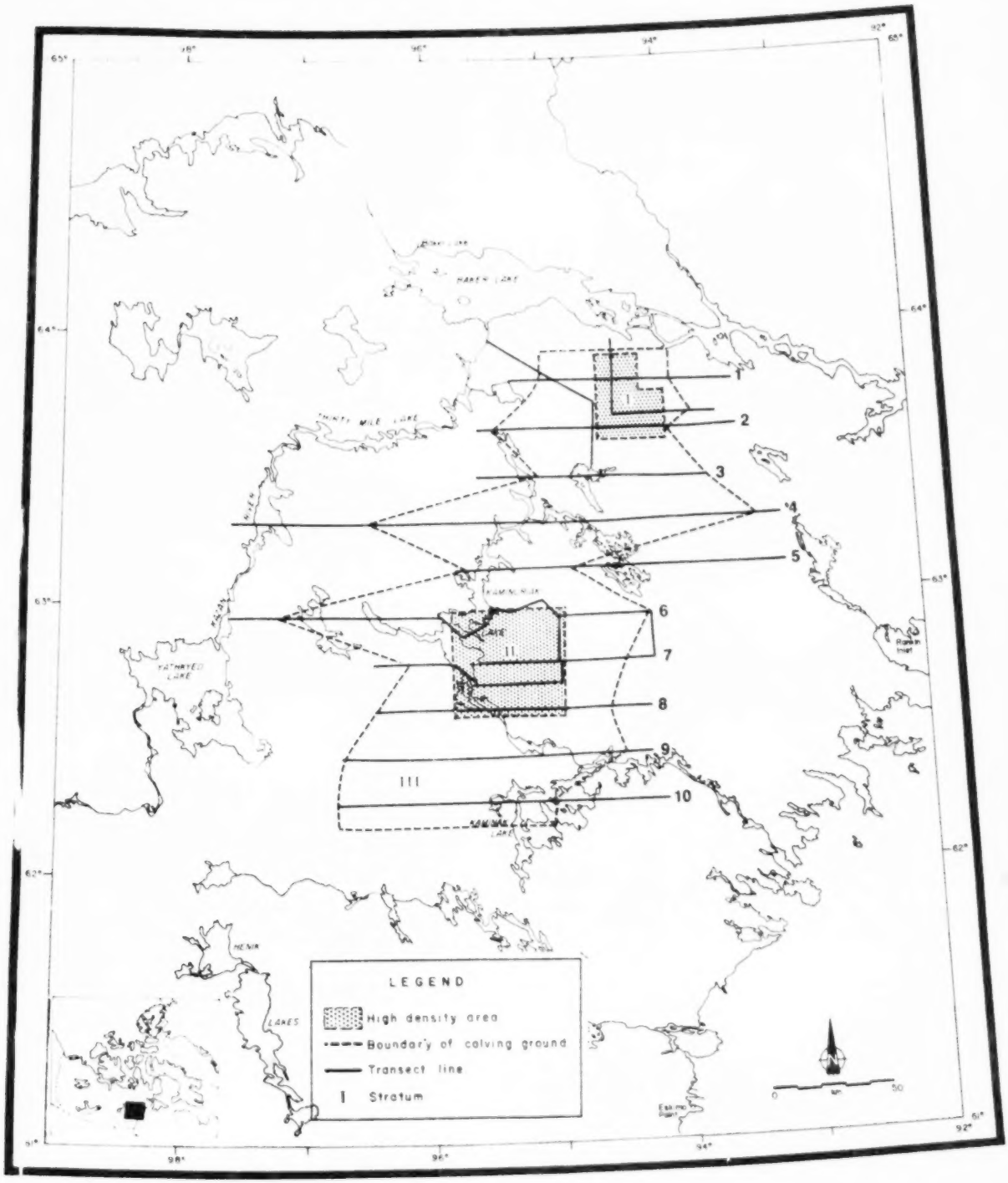

Figure 1. Placement of reconnaissance transects and the boundaries of the calving ground area showing the locations of three strata censused.

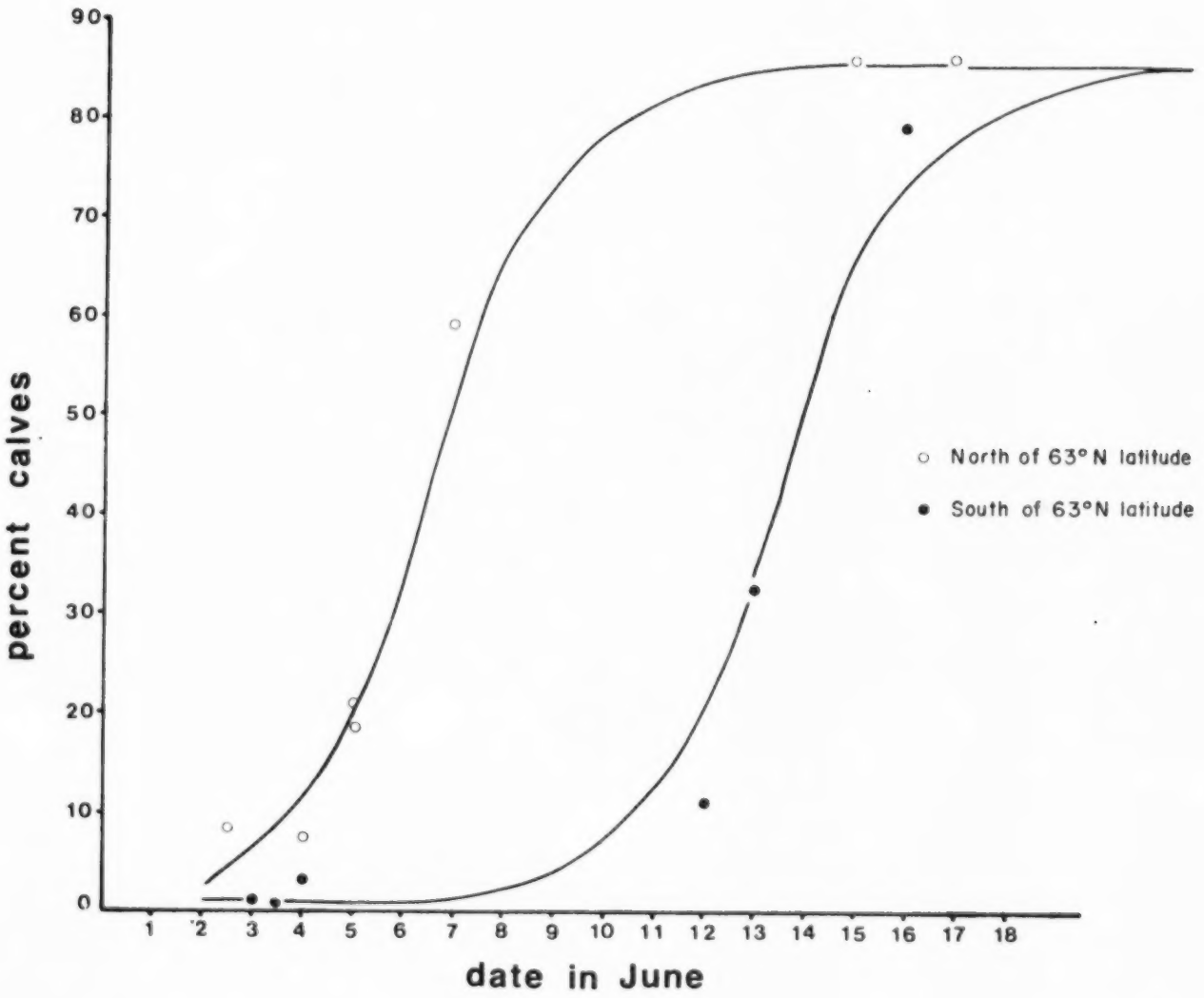

Figure 2. Percent calves in the population versus time of year for north and south parts of the calving ground.

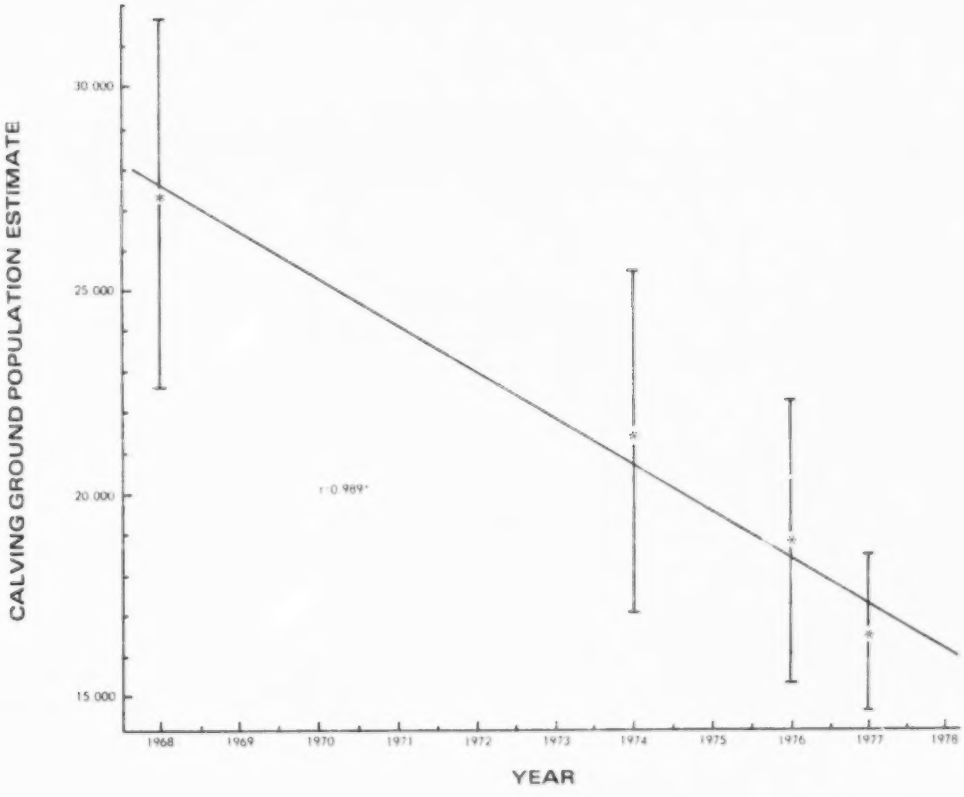

Figure 3. Change in the size of the calving ground population of the Kaminuriak herd 1968 to 1977. Vertical bars represent one standard error of the estimate.

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APPENDIX A

Table A-1. Number and density of caribou observed per transect in Stratum I.

Transect			Caribou counted					
					Both observers combined			
Number	Length (km)	Area (km^2)	Left observer	Right observer	adults[1] (Y)	calves	total	Density (caribou/km^2)
1	17.8	14.2	1	0	1	0	1	0.07
2	17.8	14.2	4	3	7	0	7	0.49
3	17.8	14.2	247	203	328	122	450	23.10
4	17.8	14.2	191	103	291	3	294	20.49
5	17.8	14.2	169	115	264	20	284	18.59
6	17.8	14.2	51	65	85	31	116	5.99
7	27.4	22.0	25	9	29	5	34	1.32
8	27.4	22.0	56	41	79	18	97	3.59
9	27.4	22.0	188	52	201	39	240	9.14
10	27.4	22.0	37	43	52	28	80	2.36
11	27.4	22.0	104	39	92	51	143	4.18
12	27.4	22.0	44	39	52	31	83	2.36
13	27.4	22.0	50	4	31	23	54	1.41
14	27.4	22.0	17	43	48	12	60	2.18
15	27.4	22.0	11	14	19	6	25	0.86
16	27.4	22.0	30	69	73	26	99	3.32
Total	380.8	305.2	1,225	842	1,652	415	2,067	99.45

[1]Adults = 1 year and older.

Table A-2. Number and density of caribou observed per transect in Stratum II.

Number	Transect Length (km)	Area (km^2)	Caribou counted					Density (caribou/km^2)
			Left observer	Right observer	Both observers combined adults[1]	calves	total	
1	45.1	36.3	6	29	35	0	35	0.96
2	45.1	36.3	29	19	46	2	48	1.27
3	45.1	36.3	4	24	26	2	28	0.72
4	45.1	36.3	10	8	17	1	18	0.47
5	45.1	36.3	20	13	32	1	33	0.88
6	45.1	36.3	36	48	81	3	84	2.23
7	45.1	36.3	9	23	31	1	32	0.85
8	45.1	36.3	23	54	68	9	77	1.87
9	45.1	36.3	6	33	37	2	39	1.02
10	45.1	36.3	68	179	223	24	247	6.14
11	45.1	36.3	89	45	121	13	134	3.33
12	45.1	36.3	99	99	160	38	198	4.41
13	45.1	36.3	75	15	81	9	90	2.23
14	35.4	28.5	32	113	138	7	145	4.84
15	24.1	19.4	17	24	41	0	41	2.11
Total	645.8	519.8	523	726	1137	112	1249	33.33

[1]Adults = 1 year and older.

Table A-3 Number and density of caribou observed per transect in Stratum III.

Transect Number	Length (km)	Area (km^2)	Caribou counted: Left observer	Right observer	Both observers combined: adults[1] (Y)	calves	total	Density (caribou/km^2)
1	35.4	57.0	17	1	17	1	18	0.30
2	44.2	71.1	20	23	37	6	43	0.52
3	70.0	112.6	46	35	67	14	81	0.59
4	141.6	227.8	7	8	13	2	15	0.06
5	86.9	69.9	-	33	32	1	33	0.46
6	102.2	164.4	32	32	63	1	64	0.38
7	42.6	68.5	36	11	47	0	47	0.69
8	49.1	79.0	48	15	62	1	63	0.78
9	119.9	192.9	91	45	136	0	136	0.71
10	82.9	133.3	45	14	57	2	59	0.43
Total	774.8	1,176.4	342	217	531	28	559	4.92

[1]Adults = 1 year and older.

APPENDIX B. Calculation of the Standard Error of the Total Population Estimate.

The total population estimate obtained in this study was a function of four parameters. Because each parameter was estimated from a sample count, each estimate was subject to sampling error. The variance of the total population estimate is a function of the variances associated with each of these four parameters. The theoretical relationship between variances is a follows (Conrad Wehrhahn personal communications):

A) if $W = (X)\ (Y)$

then $VAR(W) = (X^2)\ (VAR(Y)) + (Y^2)\ (VAR(X))$

B) if $W = X/Y$

then $VAR(W) = (1/Y)^2\ (VAR(X)) + (X^2/Y^4)\ (VAR(Y))$

The variance of the four parameters are:

1. Calving ground population estimate 16,503; variance 3.747×10^6 (Table 2).

2. Proportion of breeding females on the calving ground 0.896; variance 0.00145 (var = S.E.^{2}, Table 3).

3. Proportion of females in the population 0.604 (Table 6); variance assumed to be 0.00215 based on a 95% confidence interval of 10%.

4. Proportion of females that breed 0.694; variance cannot be measured so a modest estimate of 0.00120 assumed based on a 95% confidence interval of 10%.

The population estimate is:

$$\frac{(16,503)\ (0.896)}{(0.604)\ (0.694)} = 35,276$$

To calculate the variance on this estimate, I treated the calculations as three separate steps so that they corresponded to the theoretical relationships:

1. $(16503)\ (0.896) = 14,787$ (A)

2. $(14787)/(0.604) = 24,482$ (B)

3. $(24482)/(0.694) = 35,276$ (C)

The variance of the total population estimate was calculated as follows:

1. $\text{VAR}(14{,}787) = (16503)^2\ (.00145) + (0.896)^2\ (3.747 \times 10^6)$

$= 394{,}906 + 3.009 \times 10^6$

$= 3.404 \times 10^6$

2. $\text{VAR}(24{,}482) = (1/0.604)^2\ (3.404 \times 10^6) + (14787^2/0.604^4)\ (0.00215)$

$= 9.32 \times 10^6 + 3.53 \times 10^6$

$= 12.85 \times 10^6$

3. $\text{VAR}(35{,}276) = (1/0.694)^2\ (12.85 \times 10^6) + (24{,}482^2/0.694^4)\ (0.0012)$

$= 26.68 \times 10^6 + 3.10 \times 10^6$

$= 29.78 \times 10^6$

The 95% confidence limits of the total population estimate (35,276) are:

$\pm\ (1.96)\ (\sqrt{\text{Var}(35{,}276)})$

$= (1.96)\ (\sqrt{29.78 \times 10^6})$

$= (1.96)\ (5457)$

$= 10{,}696$

$= 30.0\%$ of the estimate

The 95% confidence interval is therefore:

$35{,}276 \pm 10{,}696$

or 24,581 to 45,973 caribou.

There is no reliable estimate of observer bias, let alone an estimate of its variance. When corrected for an observer bias of 20%, the 95% confidence interval becomes:

(1.25) (24,581) to (1.25) (45,975)

30,726 to 57,466